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AN ANALYTICAL APPROACH TO DESIGN A DIAGRID FRAME BUILDING WITH THE VARIATION IN THE BRACING ANGLE

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Abstract: Various composite structures are building now a days but there are some studies on “Analysis of Diagrid Frame Structure”, & “Moment Frame Analysis” as obtained through the various literature. In the present study, three models of 234m height (different angle of bracing) based on diagrid structure with identical floor plan (53m X 53m), geometry and other properties except braces and columns at exoskeleton and inner area. The models are prepared by using different angle of bracing i.e. 40^0, 45^0 and 50^0. Architectural plan is prepared on AutoCAD-2012 and STAAD Pro v8i series VI is used to analyze the different models. The wind zone-IV and seismic zone-V are selected for the study. The different models of diagrid structure as per the variation of angle have been compared on storey Displacement v/s H/500 displacement and base shear.These properties are obtained for all the models and results compared to achieve the optimum bracing angle for diagrid structure. It is reveled from the results that model having lower angles are good against wind pressure, further model with higher angles is good against seismic forces because of the less base shear. It is also observed that close cluster of steel brace frame provide more rigidity and results in less displacements at storeys, but close cluster of steel frame cause more weight of steel. However, this study suggest that 45° brace angle provide excellent results in displacement and base shear. It is revealed that 45° angle formed geometry close to equilateral triangle formation for distributing loads more evenly when subjected to lateral loading.

Keywords: Angle, Base shear, Diagrid, Displacement, Geometry

I.INTRODUCTION

Today in modern time building requirements has been changed from conventional to exceptional. Building design is going through phase of challenging the possibilities of construction by pushing the limits of analysis and design of structural member and their connections. Steel diagrid is a modern architectural concept that has been modified. When it comes to high-rise structures, building design is a must because it affects their attractiveness. Steel diagrid increased architectural versatility and the range of geometric patterns and shapes available to architects. As it is slightly confusing by name, steel diagrid buildings are generally steel exoskeleton framed around inner core building. Now modern building design involves twisting, tilting and some other complex geometric designs in high rise segment of the building. Most of these building types uses steel diagrid concept. Few famous building names show remarkable presence of steel diagrid are “Burj-Khalifa”,“Aldar’s Headquarter”, “Capital Gate”, “Cayan Tower”, “Moon Tower”, “Swiss-Re Tower” & many more.



Fig. 1 Diagrid Structure built in world

II. LITERATURE REVIEW

Following are some important literatures which are reviewed for the study:

1. **Prajapati et al, (2021)** Among the different lateral load resisting systems of tall structures, the diagrid

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structural system is a one-of-a-kind structural system that has been shown to be successful in comparison to other bracing systems that have been increasingly popular in recent decades. Diagrids are perimeter structural arrangements with a grid of diagonal elements that are involved in both gravity and lateral load resistance. The diagrid construction assures the building's overall stiffness and strength by merely axially engaging the diagonal members and fully bracing the interior gravity columns for stability only at diagrid joints.

2. **Mathasuriya et al, (2021)** The need for high-rise structures has grown tremendously, necessitating a thorough examination of effective and modern structural systems in order to select the optimal construction for a specific situation. A tall building's structural system should be designed to enhance structural efficiency. The goal of this research is to determine the best Diagrid and Outrigger structural system configurations for tall buildings. For this analysis, a typical floor plan of 42 m × 42 m is used. E-tabs software is used to analyse the diagrid and outrigger structural system for a 60-story steel skyscraper that is subjected to lateral loading.

3. **Kiran Kamath et al, (2019)** Present analysis of diagrid structures in circular plan for different height to width aspect ratio and different brace angles. Five aspect ratios 3.6, 5, 6, 7 & 8 were considered in analysis at varying angles 64^{O}, 72^{O}, & 90^{O} between diagonal column members. Graphs for top storey displacement, time period mode shapes, inter-storey drift and lateral load distribution on diagrid and internal columns are plotted. At angle of 72^{O}, lower roof displacement and inter-storey drift are shown as compared to other angles. An increase in aspect ratio, increase in optimum angle observed. Up to angle 76^{O}, most of lateral forces are resisted by diagonal columns.

4. **Giovanni Maria Montuori (2014)** Perform analysis on high rise steel diagrid building of 351 m high with H/B ratio of 6.62. Analytical model has floor dimension of 53 m x 53 m with steel framing members as per euro steel table. Model was prepared on SAP 2000 software and analyzed for three different brace angles 60^{0}, 70^{0} & 80^{0} with and without secondary bracing system. Analysis shows need of secondary bracing system in steel diagrid building. Local inter-storey drifts are found lowest for 60^{0} angle bracing system.

5. **[Ghomi et al, 2008]** Bending and shear deflections are examples of lateral deflections in buildings. Combinations of several sorts of coupled systems can effectively manage bending deflection. However, shear deflection can be reduced by increasing the shear stiffness of structures. The new idea is introduced, and the use of the Easy-Going Steel (EGS) theory to improve the behaviour of X-bracing systems is described in this study. The application of this theory to the design of X-Braces can improve building lateral stiffness and reduce lateral displacements.

III. METHODOLOGY

For this study, three models are created. STAAD.PRO software is used to create and assess each model.Except for the diagrid angles, all models are identical, allowing us to concentrate solely on diagrid braces. Diagrid angles were created for each model, which were 40º, 45º, and 50º. Because this study is solely based on the brace angle as a decisive parameter modification for models, and the analysis results of each model are used to establish relationships and make comparisons for the study.

All models have identical floor plans as shown in figure 3.1. This model floor plan is similar to the model developed by Giovanni Maria Montour for his research paper “Secondary Bracing Systems for Diagrid Structures in Tall Buildings”. (Giovanni Maria Montuori (2014) **.** Three models having identical floor plans with different diagrid bracing angles. A total of 60 floors are encircled by diagrid braces at a fixed angle from horizon line for each model where a constant floor to floor height 3.9 m is provided throughout the building height. This make a total of 234 m high analytical building model having braces at periphery of the building with constant brace angle for each model and cross bracings for the inner core area. Columns and bracing members are provided as tube sections varying along floor height.

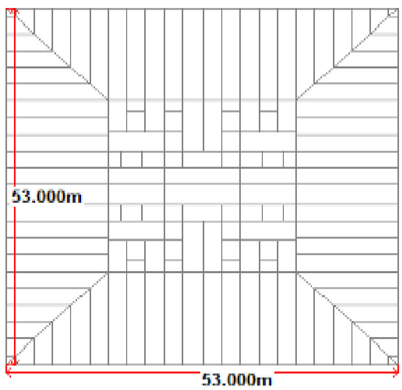

Fig. 2 Floor Plan of Analytical Model

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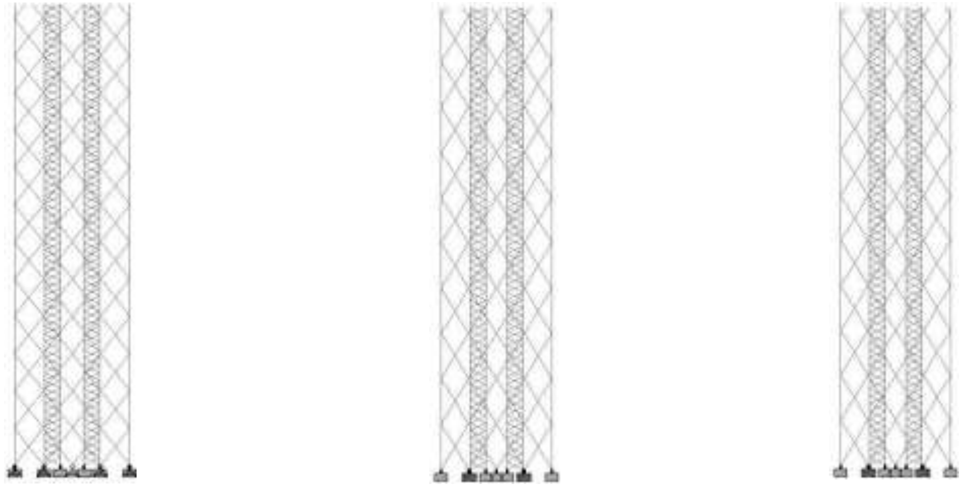

40º - Outer Braces 45º - Outer Braces 50º - Outer braces

Fig. 3 STAAD Pro Bracing Models

IV. ANALYSIS OF RESULTS AND DISCUSSION

Model - 1 Analysis of Results (40°)(X Axis)

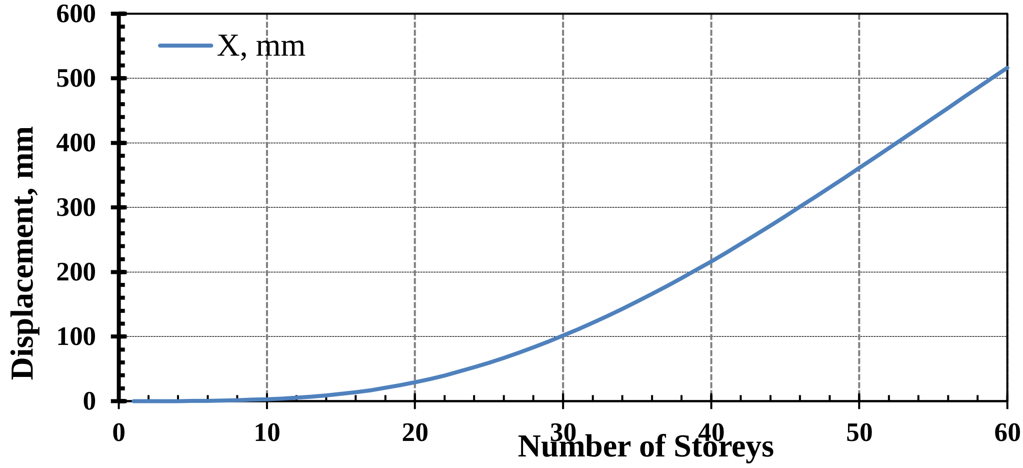

Fig. 4 Model 1:Storey Displacement on X-axis

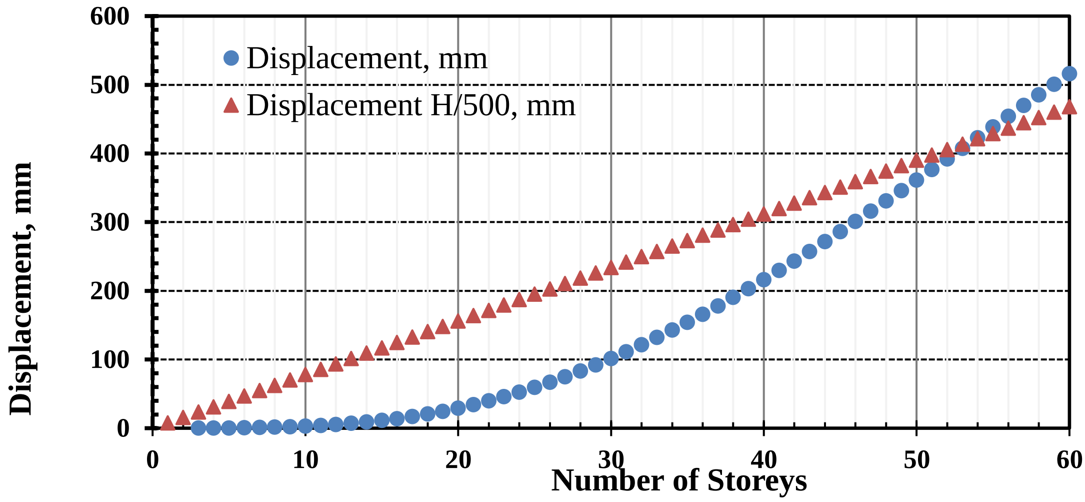

Fig. 5 Model 1: Storey Displacement v/s displacement at H/500 for X-axis

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Model - 2 (45°) Analysis of Results (X Axis)

Fig. 6 Model 2: Storey Displacement on X-axis

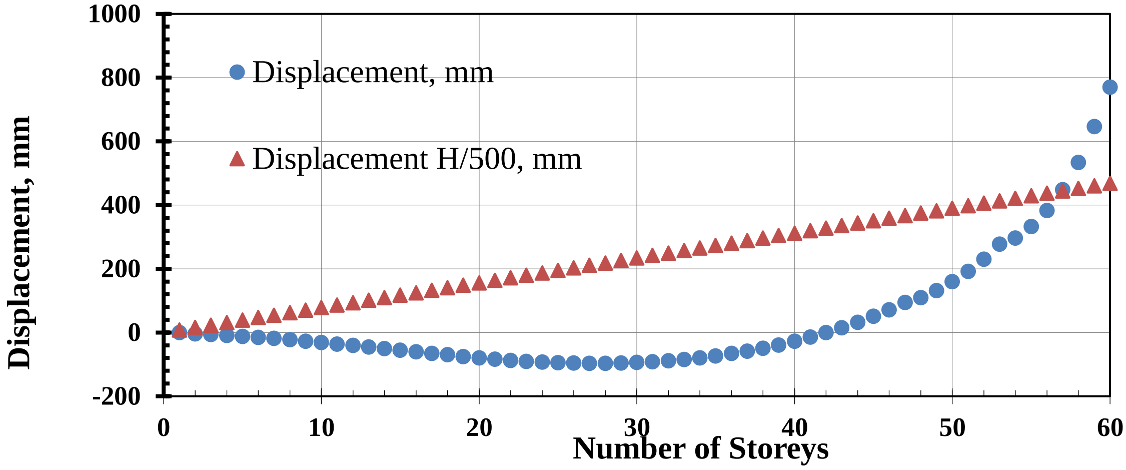

Fig. 7 Model 2: Storey Displacement v/s displacement at H/500 for X-axis

Model – 3 (50°) Analysis of Results

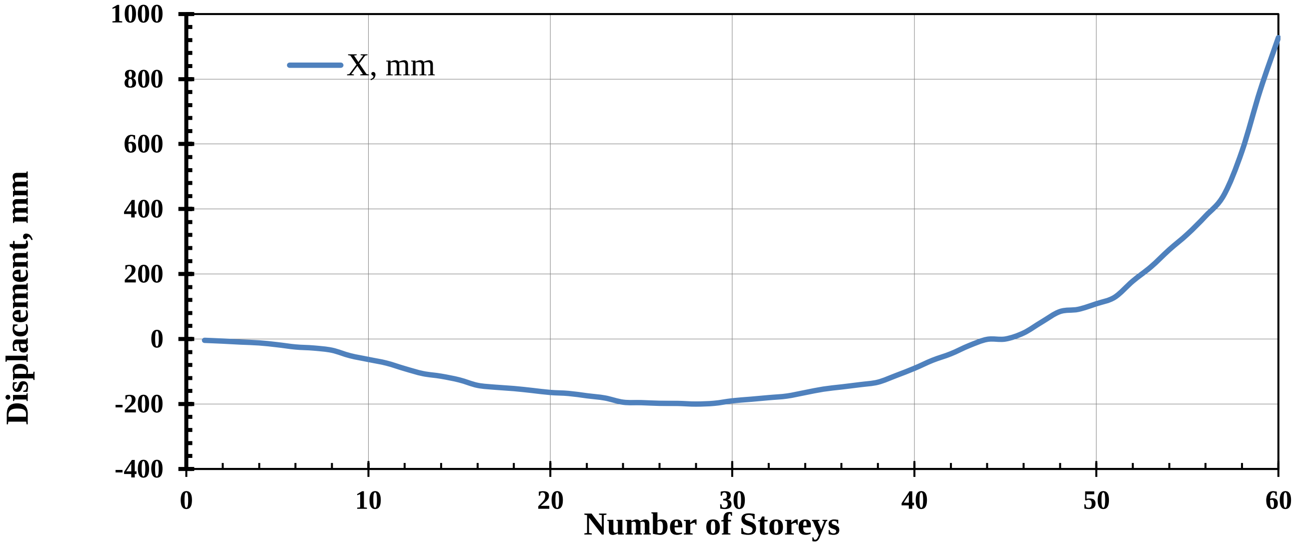

Fig. 8 Model 3: Storey Displacement on X-axis

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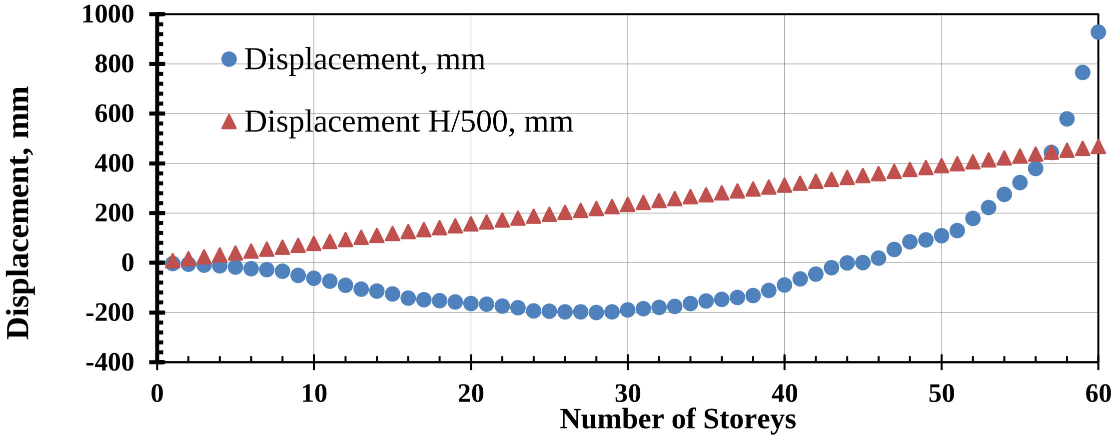

Fig. 9 Model 3: Storey Displacement v/s displacement at H/500 for X-axis

Comparative Study of All Three Models (X-Axis)

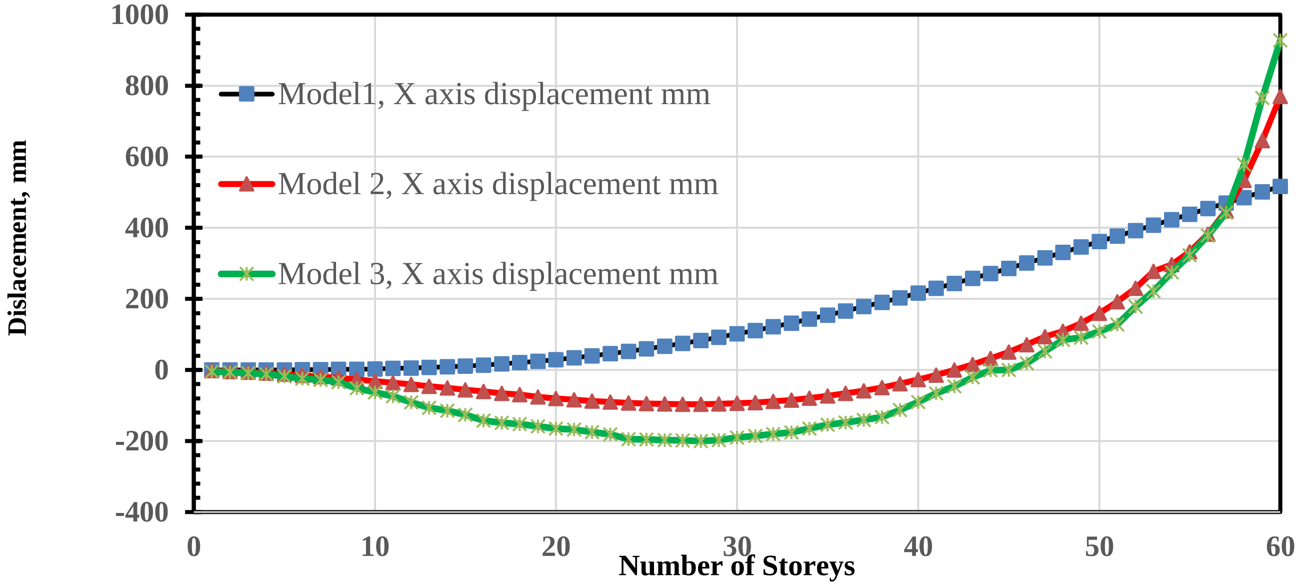

Fig. 10 X-Axis Displacement Comparison for All Models

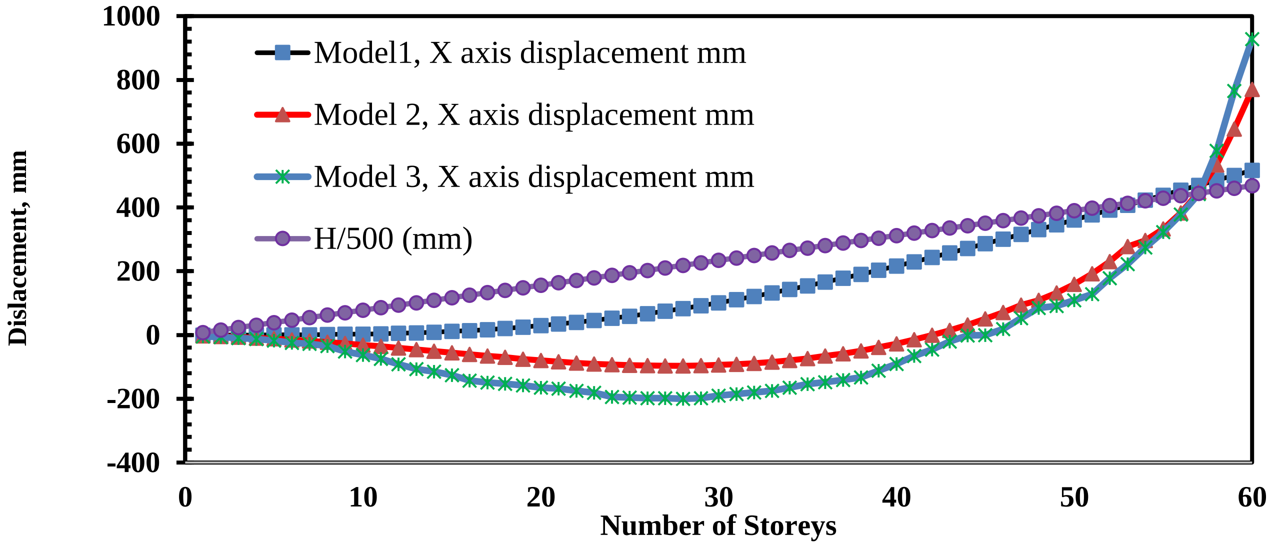

Fig. 11 Displacement v/s displacement at H/500 at X – Axis for All Models

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Seismic Base Shear

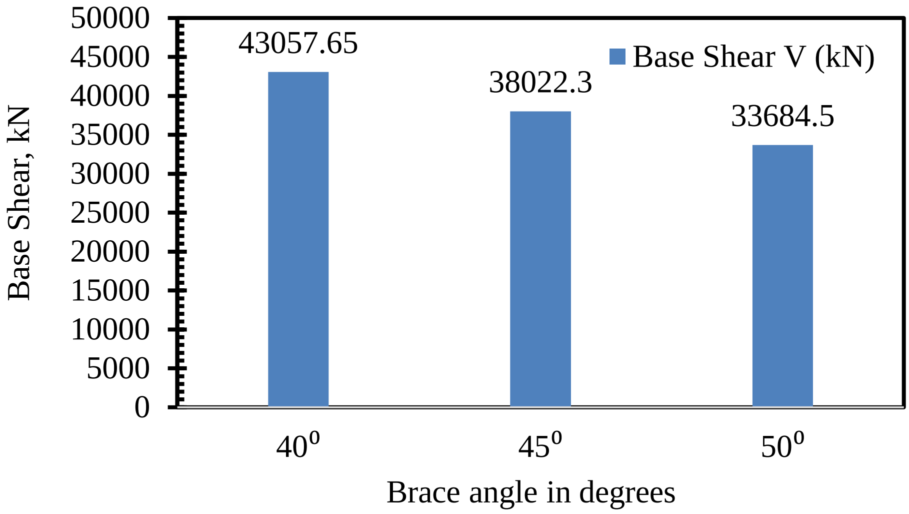

Fig. 12 Brace angle vs Base Shear

V. CONCLUSION

Model-1:

- It is designed for 40° bracing angle and after analysis it is obtained that this model have less displacement in major axis (x-Axis). The beams will bend due to lateral forces and column will face lateral force directly. Whereas the bracing will carry axial force which will be distributed from beam to bracing. Lesser angle provides more rigidity to the beam hence transfer of axial force also lowered which ultimately decreased the displacement.
- The close cluster of frames due to less in the size of bracing angle resulting highest weight of model-1. Due to this, the base shear also increases for the structure because base shear is directly proportional to weight of building and obtained result revealed that model-1 has highest values of base shear.

Model-2:

- It is having bracing angle 45º getting more displacement and less base shear as compare to model-1. This is due to the reason that weight of the structure is decreasing with increase in the bracing angle which ultimately increases displacement values in x axis but lower the base shear values.

Model-3:

- Results shows highest displacement values in model-3 having brace angle 50º in X axis. Because higher angle of bracing, lowers the density of structure which ultimately increased the displacement values.
- This model also shows lowest values of base shear, as low density of steel makes less weight of structure.

Results obtained from graph 4.18, shows that the maximum displacement for model-1 with respect to H/500 displacement graph is at 54 storeys, for model-2 it is at 57 storeys, and for model-3 it is at 58 storey in X axis. These changes observed in the storey displacement value with H/500 displacements is due to change in bracing angle as higher the bracing angle the interaction of storey displacement with H/500 is also at higher storey.

Hence, as per the obtained result model-2 which is having 45° bracing angle gives optimum result on displacement and base shear among all three models. The bracing angle 45° is effective in the distribution of forces. So, this is another reason to select 45° as optimum.

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